THE VIRTUAL FLIGHT RESEARCH CENTER:

AN ENVIRONMENT FOR COLLABORATIVE LEARNING

A Learning Technologies Project Proposal
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Submitted by

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SUMMARY

A workforce that continuously innovates and advances a technology base that is a keystone in the economy must be continuously educated and prepared for future challenges. Within the United States there are indicators pointing to an impending crisis situation with the health of the science and engineering workforce. NASA, with its exciting missions and evolving technological capabilities, is in a unique position to address this challenge. We propose the construction of a prototype virtual flight research center that establishes the capability to extend flight test and research activities to any classroom. More than the ability to remotely observe other's activities, our solution evolves a comprehensive and extensible interactive environment designed to give instructors easily managed access to remote data sources potentially diverse in both space and time. In doing so, the instructor is able to augment curricula with interactive access to live or simulated live activities and permit on-demand, hands-on experimentation in the classroom to reinforce concepts being taught. Conversely, the classroom becomes an augmentation of the original activity, potentially adding significant value to the larger research or test objectives. Immersed in a virtual presence environment like this, students engage in more collaborative exchanges and benefit from the experience of adaptive learning.

NASA OFFICIAL ENDORSEMENT AND SPONSORING CENTER

Dryden Flight Research Center sponsors and endorses this proposal. The

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INSTITUTIONS INVOLVED IN RANKING ORDER

1. NASA Dryden Flight Research Center
2. Naval Postgraduate School, Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS)
3. Longitude 122 West
4. Creare, Inc.
5. California Polytechnical University, San Luis Obispo
6. Purdue University
7. NASA Ames Research Center
8. NASA Jet Propulsion Laboratory
9. Mission Research Corporation

PROPOSAL CONTENTS

TITLE OF PROJECT

The Virtual Flight Research Center: An Environment for Collaborative Learning

BUDGET AND MILESTONES

The proposed Phase I effort requires a supporting budget of $180,000. Budget and current project status will be reported bimonthly via a dedicated task to support that effort. In addition, individual tasks have the following major milestones identified assuming funding in place by June 2002:

Milestone 1: Collect Use Case scenarios.	11/02
Milestone 2: Define System requirements	4/03
Milestone 3: Interface RBNB to CIRPAS	1/03
Milestone 4: Develop Evaluation Plan	3/03
Milestone 5: Demonstrate Prototype	12/02, 3/03
Milestone 6: Final Report	6/03

PROJECT PURPOSE

The Need

In a recent NASA webcast sponsored by General Sam Armstrong, Dr. Shirley Jackson reported on a recent meeting with the Government, University, Industry, and Research Roundtable. The Roundtable participants were asked three questions about the science and engineering workforce and potential impending shortage in the coming decade. “The Roundtable reached a general consensus that the indicators reflect areas of concern,” remarked Dr. Jackson. She went on to say that the prospect of an impending shortage in the science and engineering workforce “is a NATIONAL issue which is shared by all segments of the Roundtable.” Dr. Jackson went on to describe the need to look for multiple solutions and “recognize the necessity for action at all points along the educational pipeline: K-12, collegiate level, graduate, and post graduate levels.”

Now, more than ever, it becomes imperative that NASA creates learning opportunities that draw students into aerospace engineering and technical fields. NASA, with its exciting missions and evolving technological capabilities, is in a unique position to address this challenge. The need from the perspective of NASA’s Aeronautical Enterprise is to increase the number of students who choose to pursue careers in aerospace engineering and related technical fields. This need is reflected in the *Aeronautics Blueprint*, the integrated strategy for NASA’s Aeronautics enterprise to “focus its research capability and develop a collaborative R&D network that includes academia and industry, enabling a geographically distributed but highly integrated national R&D team.” Growth and maintenance of a highly skilled workforce represents one of four Blueprint elements.

The Solution

To address this need, NASA’s Learning Technologies Project (LTP) is NASA’s educational technology incubator, focused on expanding technical and scientific literacy for the learner through innovative application of technology itself. The goal of this project is to leverage recent accomplishments in distributed computing technology to establish a prototype virtual flight research center suitable for extending flight test and research activities to any classroom. The vision is to make it easy for a flight operation, lab, or data center to permit an authorized classroom to unobtrusively "plug in" for access to live and recorded information. In doing so, the classroom essentially becomes an extension of the control room, the research lab, and the data analysis center.

More than the ability to observe remote activities, our solution evolves a comprehensive and extensible interactive environment designed to give instructors easily managed access to remote data sources potentially diverse in both space and time. By giving the instructor the ability to augment curricula with interactive access to live or simulated live activities, our system permits on-demand, hands-on experimentation in the classroom to reinforce concepts being taught. In advanced scenarios, the classroom becomes an augmentation of the original activity, potentially adding significant value to the larger research or test objectives. Immersed in this virtual presence environment, students engage in more collaborative exchanges and benefit from the experience.

The previously developed technology underlying our solution is called Ring Buffered Network Bus (RBNB). Originally conceived for automating real-time decision support systems in the control room, RBNB has evolved into a general purpose tool for solving integration problems for network application developers interested in serving engineering and science communities with dynamic, compute-intensive, or otherwise complex application integration needs. This patented and award-winning technology was conceived and nurtured within NASA's Small Business Innovation Research (SBIR) program and has found application in seemingly disparate areas such as urban warfare, disaster relief/homeland security and aircraft datalink management, in addition to network based distributed test operations.

Goals and Objectives

The vision for this project is to make it easy for a flight operation, lab, or data center to permit an authorized classroom to unobtrusively "plug in" to its data center for access to live and recorded information. In doing so, the classroom essentially becomes an extension of the control room, the research lab, or the data analysis center. Goals and objectives include:

1. To research and develop an immersive technology solution for distributing data to and amongst classroom(s) using NASA and the Naval Postgraduate School's Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) to support the improvement and enhancement of science and technology literacy in the United States.
2. To be a value added compliment to NASA mainstream R&D resources and to stimulate educational and commercial applications of NASA-sponsored Ring Buffered Network Bus technology.
3. To apply and extend our innovative technology solution for the benefit of the educational community
4. To provide replicable and scaleable demonstrations of significant value to the educational community.
5. To infuse emerging NASA technologies, R&D, and products into the learning environment, resulting in measurably enhanced instruction in science and technology.

Alignment with Learning Technologies Project Pillars

The Learning Technologies Project (LTP) is organized around three thematic technology pillars: *Interactive Environments*, *Virtual Presence*, and *Immersive Experience*. With a foundation technology that addresses general network services needed for distributed live operations, this proposal supports all three pillars of LTP.

In terms of Pillar I, Interactive Environments, our industrial and academic partnerships can contribute to "the development of a virtual NASA that extends the real world with simulated experience." (From the LTP Project Plan 2002, section 5.5.1) The project will effectively demonstrate "intelligent streaming that uses only a fraction of the data required by a video stream …and provide access to complex databases with multiple dimensions."

The project also strongly supports Pillar II, Virtual Presence. Our partnership with Creare will foster the development of innovative Internet manipulation and utilization, remote Internet broadcast capabilities, interaction with environment and NASA scientists, and 2-D over time to yield 3-D with still images and software.

The third pillar of immersive experience is also supported. Computer platforms tied to high-speed networks outfitted with multimodal displays in 3-D and 2-D, spatial and stereo sound, haptic feedback systems, olfactory emitters, and other forms of sensory transmission devices an be managed and fused with other data sources discussed in this proposal using the VFRC as the real-time fusion environment. Efforts will be made to identify examples of immersive technologies for use in Phase II (possibly from other LTP-funded efforts), but our priority here is on a system that increases ease-of-use for the classroom, adaptable to fast and slow networks, that will help integrate these components into the larger whole envisioned by LTP.

Expected Outcomes

The final outcome of the proposed effort is for students to learn and appreciate real-world science and engineering activities. The intermediate outcomes will be learning methods and materials fostered by the proposed technological developments. These could include curriculum materials, data interfaces, and demonstrations of data delivery to the classroom.

In Phase 1, realistic metrics for measuring the intermediate outcomes will be developed. An evaluation plan for assessing student learning achievements will also be developed. The deliverables that will be generated in Phase 2 will be defined. The evaluation plan is discussed further in a subsequent section.

In phase I we will also address ad hoc efforts, if any, that can or need to be addressed in order for our solution to be accessible by underserved audiences.

INNOVATION

Ring Buffered Network Bus Technology.

The underlying technology that enables our solution is called Ring Buffered Network Bus (RBNB). This innovative technology was conceived to solve measurement process automation problems for NASA. In use by NASA and other organizations for over six years, RBNB has been commercialized as the RBNB DataTurbine™ and is now at an appropriate state of maturity to consider extending it for LTP educational applications. The RBNB concept is shown in the following figure.

Figure 1 RBNB Architecture Concept

When lives and money are at stake, people have precious little time to sit around and wait for computers to add value to the decisions that need to be made. But the ever-improving capabilities of computers, networks, and the applications that they run make it possible to envision decision support systems that effectively improve the situational awareness and accelerate decision making processes of groups and individuals. Eventually, independent applications get integrated and fused while time constraints and remote participants drive us toward decision support environments that are distributed and collaborative with high performance or real-time characteristics.

For this type of environment NASA has developed and commercialized the Ring Buffered Network Bus, or RBNB DataTurbine.. This Java middleware solution is a cost-effective network cache for high performance hierarchical peer-to-peer computing, collaborative information processing, and interactive application integration problems. An extension of publish-subscribe technology, it is particularly well suited to network-based data acquisition and processing requiring time-based access and correlation across diverse and geographically distributed nodes. It's role as an intermediary enables users to independently scroll back and forth through time on distributed data that may be continuously updated. Application examples include virtual presence environments with video-on-demand or other sensor-history-on-demand capabilities, temporary source-side measurement storage service for later transmission across intermittent links, and services for integration, fusion, and data management within web-based emergency operations infrastructure.

Related Technologies

Ring Buffered Network Bus is middleware server that implements a hierarchical peer-to-peer network of dynamically configured ring buffers. The idea is that this server-in-the-middle is useful for offloading or otherwise decoupling data source and data destination. There are some applications available that implement a subset of this capability but tend to have been designed with specific uses in mind. Web proxy servers are an example of a buffer-in-the-middle application. Conversely, there are middleware "software bus" and "message-oriented" middleware products that provide generic publish-subscribe services but these products typically are focused on transport of current values and are not well designed for continuous streaming. A third family of products is distributed computing middleware. These products are often platform specific and/or tailored to large parallel computing problems, whereas RBNB is geared more toward collaboration of components that more likely are doing different things in sequence or iteration.

To compare and contrast RBNB with technologies that overlap in function would consume many pages. Instead, we offer two simple discussions that highlight the innovative nature.

TiVo™ (www.tivo.com) is a digital video recorder, like a VCR but with a disk drive instead of videotape. It exists as an intermediary between the TV signal and the television. The user can receive data, store it, and scroll back and forth through time. Now, imagine a web of Tivo boxes that allows your TV to see what's on other TiVo boxes. Next, imagine replacing your TV with a bi-directional link so you have the option of becoming a TV studio. Finally, imagine a TV that accepts or generates any data type (i.e. a computer) and allow an arbitrary number of them to plug into your home TiVo box. This scenario is the service delivered by RBNB.

Now imagine your web browser. There exist "Forward" and "Back" navigation buttons that allow you to quickly re-navigate across the URLs you've been to already. From a measurements or signal processing viewpoint, these buttons are *spatial* controls, analogous to different sensors on an aircraft or (from different websites) different aircraft. The problem with the browser is that each time you click, you *only get the most recent value*. In order to easily use the browser technology to managing flight data or *any live data stream*, the end user needs to specify duration in time. In other words, *web browsers lack temporal controls, and those controls are necessary to fully integrate live information streams and interactive collaboration environments into the web infrastructure*. Commercial content distribution providers like RealNetworks (www.realnetworks.com) go outside the web infrastructure and target bandwidth-hungry audio and video data, without much regard to collaborative applications. If you can imagine a web infrastructure where browsers have temporal controls enabling seamless, integrated access to information across space and time, you understand the long-term ramification of RBNB technology.

DIFFUSION POTENTIAL

The potential for diffusion, replication, and long-term success is quite high for the following reasons:

Designed for replication. While we target a specific data source and during our phase II project implement and study a small set of possible scenarios, our design intentionally makes it easy to experiment with small and large scale permutations on variables:

- One-classroom scenarios easily scale to many-classroom scenarios

- A substitute data source is straightforward. For example, NASA Dryden can substitute for CIRPAS or a classroom can become the data source, feeding data to another classroom. This latter concept is appealing since it effectively provides a type of gaming environment that allows classrooms to interact with each other in a collaboration network.
- The classrooms can be replaced by research labs. This statement is justified since the underlying technology was created and is used by research labs already. Since researchers are professional learners, continued use of this system by industry can sustain the innovation after the conclusion of phase II. The notion that the tools being used by classrooms and industry start to merge in this world of network collaboration implies a potential for huge gains in teaching science and technology.

We understand the common denominators. The problem of managing live data over potentially bandwidth-limited and intermittent network links exists wherever people are trying to automate processes involving measured data. Qualities of service parameters like *latency* and *jitter* (variance) of the network services will vary and the solutions to abstract issues like *metadata management* and large-scale *interoperability* are still evolving. In addition, a clear understanding of the concept network-distributed operations is in fact a reoccurring challenge that must be overcome in order to discover the optimum solution. For classroom use of collaboration technologies, our project is the type of activity required for that discovery to occur.

Our solution is simple and cost-effective. The architecture of RBNB simplifies the task of building collaboration tools by decoupling source and destination using a high performance and if necessary sophisticated network of storage servers tailored to collaboration tasks. The sophistication in the RBNB network service leads to simplicity in the higher-level applications. The RBNB server software is *free* to end users, meaning that obtaining the core capability is as simple as pointing a browser to http://rbnb.creare.com, downloading, installing, and starting the server on one or more computers. Costs associated with integrating new data sources are non-recurring, development of whole new applications is reduced, and evolution of interoperability across dissimilar third party software packages promotes competition in price and functionality.

We are improving on existing approaches. There are a number of ad collaboration tools that typically focus on a specific data type or have made assumptions on the intended use of that data. Turning data into information and making it available in a form tailored to end-user needs is *the* major challenge facing business, government science, engineering, and education communities. A flexible, adaptable, high-performance information grid that serves as the glue to join existing and future system-centric tools into a system of systems is a precondition to meeting this challenge. Our focus on the role of the conduit independent from any specific application that plugs into it enables us to discover and understand how existing approaches are limited and how they can be improved. When attached to an RBNB backbone, sources of static and dynamic data, analytic and fusion applications, geographic information systems, streaming audio and video data sources, and graphical display tools and decision aids come together to provide a high-performance integrated system of systems. This network of interconnected data servers and clients on top of the existing infrastructure creates a robust, reliable, and accessible extended virtual information system that is shared by all participants.

RBNB uses platform-independent Java code and standard network protocols. It provides RAM and disk based "ring" buffers between data sources and analysis and display applications. These eliminate the need for direct application-to-application links, facilitate integration of disparate standalone analytic and processing tools, and provide a framework for dynamic processor and bandwidth management.

We intend to propagate the results of our work. As demonstrated by our proposed establishment of an interdisciplinary advisory board, our plan is to begin communicating with cognizant advisors, potential value-added developers, and user communities at an early stage. Phase II efforts shall include information dissemination via conference papers, NASA technical documents, and website document and software availability. NASA Public Affairs will be employed to assist us in advertising successes at an appropriate time. Website statistics will provide one leading indicator of our success in communicating our results, and metrics will be identified to track actual propagation of the use of our tools.

PROJECT FEASIBILITY

Technical Approach

The technical objectives of Phase I are to demonstrate the feasibility and technical merit of bringing live flight test data into the classroom for educational use. In order to achieve this objective we will have to answer the following questions:

- Can we easily integrate CIRPAS data sources as a consumer and producer of information to/from the RBNB environment, which adds value to their current capabilities and further enables independence from vendor-specific or platform-specific end-user applications?
- Are the common bandwidth capabilities for classrooms adequate for delivering useful quantities of CIRPAS data?
- Can we identify a useful set of "Use Case Scenarios" that define how teachers and students would benefit from the capability, and can we identify a subset of these use cases for implementation and analysis in Phase II?
- Can we identify an adequate set of metrics and associated evaluation processes through which we can observe progress toward desired educational outcomes.

Work Plan

In order to achieve our Phase I goals, we have organized this project into six tasks. These tasks are discussed in this section, and an implementation schedule is proposed in the implementation section.

Task 1: Collect Use Case Scenarios

Learning tends to progress from specific experiences to general understanding. Our first task is to collect specific *use cases* that help us evolve a general understanding of the concept of operations in using a virtual flight research center for classroom use. Use cases, then, become the foundation on which to design system requirements that deliver the desired functionality.

Use cases (also referred to as use case scenarios, or use case diagrams) are a technique used in developing software systems that effectively transition conceptual brainstorming to formal requirements definitions. In their basic form, the idea is to simply document how the VFRC will be used, from a user's standpoint – in this case the student, the teacher, the data or service provider, evaluators, etc. These ideas can be simple paragraphs or written descriptions. As they become formalized, Use Case Diagrams are drawn, often using modeling languages such as Unified Modeling Language, or UML. Use cases represent a method to:

- Describe the behavior of a system from a user's standpoint
- Develop a functional description of a system and its major processes
- Provide a graphic description of who will use a system and what kinds of interactions to expect within that system
- Manage the description of complex systems-of-systems with multiple "actors" that use the system

This approach helps us in describing the requirements in the analysis and design that occurs in Phase I and benefits the implementation and documentation during Phase II of this project. It offers a rigorous way to think about the tasks that "actors" must perform, the resources likely to be consumed, and, perhaps most importantly, strive for clarity and simplicity in the end product. A use case diagram is presented in the figure 2 as an example of what a resulting high-level use case diagram might look like.

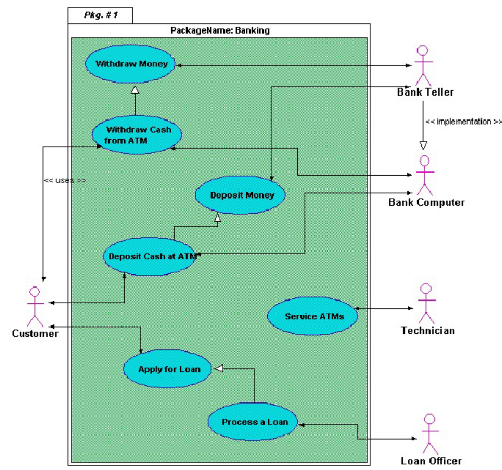

Figure 3 Use case diagram example

Task 2 Define System Requirements

The aim of this task is to define, from the use cases generated in task 1, the concept of operations for the VFRC and document the system specifications to be implemented. We will prototype in Phase I a subset of these specifications but it is expected that full implementation will be the subject of Phase II activity. Furthermore, the system specifications shall address life cycle support and maintenance aspects of the VFRC system that will be relevant beyond Phase II as the system continues to be deployed and/or propagated. Examples of topics to be covered in the system requirements include

- Concept of operations
- Data flow specifications
- Network interface and network services requirements
- Applications: user interface requirements
- Applications: programmer interface requirements
- Data rates and supporting computer system resource requirements
- Life cycle support plans

Task 3: Interface RBNB to CIRPAS ground systems

CIRPAS at the Naval Postgraduate School has developed and maintains a sophisticated data handling system geared toward their specific research needs. Because flight operations is costly and sensitive to configuration control issues, it is important to design and implement an approach that extends CIRPAS capabilities without interfering with existing operations or systems implementations. A layered approach to integration that is comprised of a CIRPAS-specific component and a generic component will be studied as a way in which to increase the diffusion potential of the end product.

The resulting design shall be implemented in prototype form and refined through iterative testing. This testing will include use of lab and office facilities as substitute classrooms in order to provide synergy with and support of Task numbers 4 and 5.

Task 4: Develop Evaluation Plan

In parallel with the use of use case scenarios to evolve technical understanding of how to implement the VFRC, use case scenarios are also used to conceive and evolve a model of the educational benefits of the VFRC. This task focuses on this model and deriving from it an evaluation plan for observing progress toward targeted outcomes. Multiple use cases could be expected to result in variations in evaluation plans, so part of this task is to interact with Task 1 activity in order to maximize the number of common denominators with respect to meaningful metrics for measuring intermediate outcomes. A set of observations, surveys, interviews, and/or test questions common to all use scenarios would facilitate evaluators in comparing and contrasting different uses of the VFRC. Additional discussion of the evaluation effort is provided is a subsequent section.

Task 5 Demonstrate Prototype

At least two demonstrations will be designed and conducted over the course of the phase I. The first demonstration is to provide early access to realistic environments and obtain feedback from people not directly involved in the project. In addition to providing a way to advertise our accomplishments to date, demonstrations help us test our assumptions such as those regarding ease of use. The demonstrations will overlap in design but may target different use case scenarios. The results from demonstrations, combined with testing amongst the internal team members, will prove very valuable in determining final system design.

Task 6 Management and Reporting

This task include management activities to ensure the project is completed on time and within budget. It also provides for bimonthly informal progress reports and a final report that includes complete documentation of all work performed during the project. Other activities on this task include routine internal management and coordination of team members and interrelated task elements.

Qualifications of Key Personnel

The following paragraphs introduce key people who will contribute to this project. They form an experienced team in the fields of engineering, flight test, network application development, systems integration, software design, data acquisition, remote sensing/processing, web-based instructional support, educational technology, and research program assessment.

Dr. Marianne McCarthy - *Education Director and DFRC Learning Technologies Manager, NASA Dryden Flight Research Center*

Dr. McCarthy is Education Director at NASA Dryden Flight Research Center and is responsible for the development and implementation of Center Specific and national NASA education programs. She started her employment at Dryden as a contractor in February 1996 and became a civil servant in 1998. Her activities include development of teacher enhancement programs, student support programs, educational technology, instructional support products and support for systemic reform of math, science and technology education. Dr. McCarthy and her team use aerospace themes and NASA's research missions as contexts for teaching and as a means of capturing students' imaginations. She worked on a multi-year educational research project with The Pennsylvania State University studying web-based instruction and learning in America's classrooms. Dr. McCarthy and her colleagues at Penn State have authored three publications on this subject and have co-chaired two NASA Learning Technologies Conferences, which studied issues facing teachers as they attempt to incorporate web-based resources into classroom instruction. In 1998 Dr. McCarthy and her colleagues were accepted to present their papers at the 1998 International Internet Summit held in Geneva, Switzerland in July. Dr. McCarthy received a Special Achievement Award from Analytical Services and Materials, Inc. in 1996 for her outstanding accomplishments as Advisor for the NASA DFRC Education Outreach Program.

Lawrence C. Freudinger - *Technical Lead, Measurement and Telemetry Networks, NASA Dryden Flight Research Center*

Mr. Freudinger currently leads Dryden in conducting measurement and telemetry network research and development. As a member of the research engineering technical staff and former technical lead for the structural dynamics group he has nearly twenty years experience in experimental structural dynamics, flight test engineering, and signal processing algorithm development. Relevant to this proposal, he co-developed the award winning and patented Ring Buffered Network Bus Data Management System (RBNB DataTurbine) and was project integration manager for an air-space-ground network link experiment involving RBNB and electronically steered Ku-band phased array antennas. Larry Currently serves as the technical program chairman for the 2003 International Telemetry Conference and represents NASA on the Joint Data Acquisition Network Standards (JDANS) Program Executive Board, a US Navy-led effort. Larry received the B.S. degree in aeronautical and astronautical engineering from the University of Illinois at Champaign-Urbana (1986), and the M.S. degree in mechanical engineering from the University of Cincinnati (1990). Also relevant to this proposal, Larry has served as the education subcommittee chairman on the AIAA Structural Dynamics Technical Committee and managed Dryden's Small Business Innovation Research (SBIR) Program.

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Susan Schoenung, *President, Longitude 122-West*

Dr. Schoenung founded Longitude 122 West, Inc., a technical consulting firm specializing in the assessment and implementation of advanced technologies in remote atmospheric sensing, environmental monitoring, combustion and propulsion, and energy and power. Current and recent clients include NASA, EPRI, DOE, and DoD, as well as private companies.

Dr. Schoenung currently serves as project engineer for NASA's Uninhabited Aerial Vehicle Science Demonstration Program (UAVSDP), where she reports to Code Y on the progress of two remote sensing missions, including the Outreach and Education element. She is also working with the Naval Postgraduate School's Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) to plan and evaluate educational activities for elementary school children to observe real-time airborne science at the CIRPAS facility. In 2001, Dr. Schoenung prepared a Create Knowledge Plan for NASA Dryden Flight Research Center (DFRC) in the area of real-time airborne science. She coordinated this effort with CIRPAS.

Dr. Schoenung has 20 years industry experience in design, analysis, experimentation, project management and technology commercialization. The emphasis of her work has been on aeronautical remote sensing systems, sensors and power technologies. Dr. Schoenung has also been involved in the design and evaluation of outreach and education programs focused on science and technology. She is the author of numerous technical publications.

Robert "Bob" Bluth – *Director, Center for Interdisciplinary Remotely Piloted Aircraft Studies, Office of Naval Research*

As a Project Manager the Ocean, Atmosphere, and Space Department, Sensing and Systems Division and Modeling and Prediction Division at the Office of Naval Research (ONR), Mr. Bluth is responsible for the development and management of science and technology projects that will enhance Navy capabilities. He has developed collaborative research initiatives with Department of Defense and other federal and foreign agency science and technology offices. He has represented ONR on various national committees to formulate and evaluate current and future science and technology initiatives.

Mr. Bluth has developed new research technologies that support utilization of Remotely –Piloted Aircraft (RPA) for atmospheric and oceanographic research. The RPA technology which he manages includes development of scientific instrumentation, tactical sensors, research empathize airframes, remote flight control systems, data management systems, oceanographic measurements, but all support unique measurements strategies which would be difficult or impossible with a manned aircraft. The RPA projects also supports UAV science and technologies tasks. Prir to his current assignment Mr. Bluth was an intelligence specialist with the Naval Intelligence Command specializing in monitoring and analysis of Soviet remote sensing activities. He liaisoned with a wide array of agencies, and a number of his written analyses have been published through wire services and defense intelligence publications.

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Matthew J. Miller - *Manager, Scientific Data Products, Creare Inc*.
Mr. Miller has been responsible for structural and dynamic analysis, software development and applications in real-time data acquisition, and energy systems modeling. Mr. Miller has provided technical and management leadership for a broad range of software and data acquisition systems. In particular, he has been the key developer and manager of Creare's Scientific Data Products (SDP) including the RBNB software, which have been used by NASA, NIH, national labs, and various aerospace companies. He has also directed large system integration projects for commercial customers, implementing turnkey engineering test data acquisition and reduction systems.

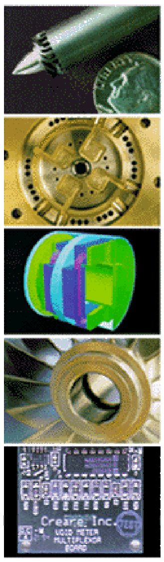
Facilities

All key personnel are backed by solid organizational resources of relevance to this project.

NASA Dryden Flight Research Center is the Agency's center of excellence in atmospheric flight research. As our namesake Hugh L. Dryden succinctly stated, flight research separates "the real from the imagined," and makes known the "overlooked and the unexpected problems." Over the past 50 years Dryden research has lead to major advancements in the design and capabilities of many civilian and military aircraft. The history of the Dryden Flight Research Center is the story of modern flight research in this country.

Dryden's measurement networks laboratory is the place where much of Dryden's technical activities concerning this project will take place. The measurement networks lab houses numerous state-of-the-art Linux and Windows-based workstations and servers along with firewall and network switch hardware. In this lab an interdisciplinary team conducts R&D in wired and wireless measurement networks, content distribution, and documentation networks. Recent research associated with this lab includes scalability of flight data distribution and distributed computing systems, Linux-based real-time embedded systems, wireless sensor networks, satellite communications, and various applications of measurement networks. The Lab can generate simulated data for use in this project or actual flight data can be made available.

The Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) was established by the Office of Naval Research in the spring of 1996 to provide Unmanned Air Vehicle (UAV) flight services to the scientific and RDT & E communities. The Center's activities have expanded to include military exercises and operational demonstrations. CIRPAS is a Research Center of the Naval Postgraduate School. The California Institute of Technology is the CIRPAS prime contractor. CIRPAS operates a variety of UAVs and manned aircraft including, but not limited to Predator, Altus, Gnat-750 UAVs, Pelican (Predator UAV surrogate) and a Twin Otter. The CIRPAS Ground Control Stations are interoperable among the Center's UAVs and surrogate. CIRPAS provides turnkey UAV operations, relieving the customer of payload integration, flight safety and logistics tasks thereby allowing the user to concentrate on his specific mission requirements. CIRPAS flight operations and the maintenance facility is located at Marina Municipal Airport, formerly Fort Ord's Fritchie Field. CIRPAS also has a UAV flight operations facility at McMillan Airport, within the restricted airspace of Camp Roberts, California. In addition to the aircraft, CIRPAS maintains and uses a wide variety of aircraft positioning, air data, and atmospheric sampling instrumentation useful to the educational aspects of this project.



Creare was founded as an engineering *service* company in 1961. Its founding objectives include performing technically excellent work, focusing on results, providing an optimum environment for creative people, and commercializing innovations by the creation of autonomous product companies or licensing to existing organizations. Their commitment to commercialization is evidenced by the establishment of a number of *independent* product businesses since Creare's founding: a leading international supplier of plasma-arc torches founded in 1968, a manufacturer of noninvasive medical instruments, a precision motion controls company, a manufacturer of color ink-jet printers, a geotechnical instruments company, a developer of biotechnologies for continuous production of pharmaceuticals, the world's leading supplier of computational fluid dynamics software, and a provider of micromachining technology. The latter three of these companies were created, or their growth directly assisted, as a result of federally funded SBIR projects. Their product sales are almost exclusively to *nonfederal* marketplaces. These firms now generate revenues of over $230 million per year and employ over 1,300 people. In April 1999, Creare launched a family of products for the management of real-time or on-line data in collaborative environments based on the Ring Buffered Network Bus technology developed through NASA Dryden SBIR support.

Implementation Schedule

The following table describes our estimated implementation schedule for the six tasks described in the project feasibility section.

Table 1 Project Schedule

TASKS	Months after award											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1: Collect Use Case scenarios	■	■	■	■	■	■						
Task 2: Define System requirements						■	■	■	■	■	■	
Task 3: Interface RBNB to CIRPAS	■	■	■	■	■	■	■	■				
Task 4: Develop Evaluation Plan		■	■	■	■	■	■	■	■			
Task 5: Demonstrate Prototype							■			■		
Task 6: Management and Reporting												
Reporting Milestones		•		•		•		•		•		
Final Report												•

Privacy and Confidentialityof End Users and Beneficiaries

The project team recognizes that with evolution of network collaboration and the intentional collection of metrics on educational value are risks that potentially disseminate information in undesirable ways. Much of NASA's data collection and flight test activity is sensitive while it's being collected as may be the knowledge gained. Issues such as security, integrity, and privacy of end users of the virtual flight research center will be addressed through the use case and requirements definition phases of our project.

Elements of evaluation plans such as surveys could identify individuals, implying additional responsibility on our part to protect that data.

It is our intent to protect the rights and well-being of human subjects of research and comply with the basic ethical principles for the use of human subjects: respect for persons, beneficence, and justice. Participation in this study will be voluntary. Informed consent forms will be given to the subjects prior to participating in the study. Subjects will be given the opportunity to read the consent form and ask questions. The signed forms will be collected at that time and a copy will be provided to each subject. Since participation is voluntary, subjects will be allowed to withdraw at any time. Information collected from each individual will be anonymous. No personally identifying information will be obtained from each participant. A code number will be used on each form such as the last four digits of their social security number to insure anonymity.

Projections for Ongoing Expenses and Potential non-Federal fund sources

Our desire to maximize diffusion potential drives us toward low total cost of ownership beyond Phase II. The basic plan is to prototype a viable VFRC at the conclusion of Phase II that demonstrates the ability to add value to science and technology education. Most or all of this basic capability will be available at no cost to end-users. Ongoing expenses are tied to services delivered in the use of the VFRC system or its derivatives. Several options will exist to enable non-federal funding to continue growing the system. A few examples are provided below:

- Third party developers of CIRPAS data management infrastructure could ingest the VFRC as part of future systems designs, thereby allowing the CIRPAS system to evolve as needed by CIRPAS, after this project team disbands. This path adds depth and continuous improvement to the CIRPAS flight test application
- Educational organizations could contract with project participants or heretofore unknown third parties to provide maintenance, engineering, or operational support services for VFRC. This path would likely include rapid broadening of the scope of VFRC to non-flight test applications.
- The results of this project are readily adapted to advanced collaborative applications. It is possible that our success could be leveraged by non-government third parties to either build similar applications in non-classroom domains or introduce whole new options for the classroom that plug into the VFRC yet in some fashion compete with the applications we've built.

PARTNERSHIPS

In order to accomplish the project's goals and objectives, the Principal Investigator and Co-principal Investigator enlisted several partners both within NASA and external to NASA.

The Naval Post Graduate School's Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) and Longitude 122 West began developing a partnership with Dryden in May 2001 with discussions of using CIRPAS' twin otter aircraft to download remote-sensing and aeronautical data to a classroom setting. The initial discussion identified the potential for including K-12, undergraduate and graduate students in a simulation of Mission Control, exciting student interest by making the activity real-time, using real data. Longitude 122 West, a woman-owned company, would be part of the education development team and help evaluate the project.

It was in those early discussions that Ring Buffered Network Bus was identified as a newly developed technology that would enhance/facilitate the distribution and display of the data. This began the partnership between Dryden's Education office, the DFRC Research Engineering Directorate and Creare, an engineering services company and small business generator.

Dryden's Education office is part of the larger organization of Public Affairs, Commercialization and Education. The project will involve at least three of the educational specialists whose responsibilities will be to develop scenarios for utilizing the NASA (and other) data for K-12 instruction in science, math, technology and geography. The investigators will coordinate with the other branches of the organization for the benefit of the project.

Ames Research Center was contacted to discuss the potential for partnering with NASA's Quest program to identify educational audiences who have participated in NASA's networked learning opportunities.

Advisory Board

Because the project outcome is highly interdisciplinary, the project leads created an advisory board that will support the project by establishing communication across disciplines, establishing working relationships with potential phase two partners, create synergy and keep the project on track.

Dr. Daniel J. Biezad, California Polytechnic State University, San Luis Obispo

Dr. Biezad is currently the Chair of the Aerospace Engineering Department in the College of Engineering at Cal Poly State University. He has related academic experience as the Associate Dean of the Air Force Institute of Technology (1988-1989) and as Deputy Head and Head of the Electrical Engineering Department at AFIT (1986-1987). He is an Associate Fellow of the AIAA, a Senior Member of the IEEE, and a member of Eta Kappa Nu. Dr. Biezad teaches and does research in the area of piloted flight control and simulation. He has authored a book published in 1999 in the AIAA Education Series titled "Integrated Navigation and Guidance Systems." He has also published approximately 55 technical articles, including book chapters on systems identification and piezoelectric actuators, three magazine articles, and eight journal publications. Dr. Biezad teaches short courses in satellite navigation and integrated aircraft systems to the Navy at China Lake and Pt Mugu Naval Air Stations, the USAF Test Pilot School at Edwards Air Force Base, California, and to the national guidance and control conference sponsored by the American Institute of Aeronautics and Astronautics.

Dr. Biezad has over 4,000 hours of flight experience in both fixed-wing and rotorcraft including pilot instructor duties at the USAF Test Pilot School, Edwards Air Force Base, California. He also has been an Air Force test engineer for remotely piloted vehicles and missiles. He received the B.S. in electrical engineering from the Illinois Institute of Technology (IIT-1966), the M.S. in astronautical engineering from the Air Force Institute of Technology (AFIT-1972), and the Ph.D. in aeronautical and astronautical engineering from Purdue University (1984).

Douglas E. Adams, Ph.D. – *Assistant Professor, Ray W. Herrick Laboratories, Purdue University*

Dr. Adams is the principal investigator on a grant from the Department of Undergraduate education at the National Science Foundation, aimed at increasing exposure of students to the value of experimental data through the use of a "roving laboratory". Dr. Adams has conducted analytical and experimental research

in the areas of nonlinear dynamics, structural vibrations, acoustics, noise and vibration control, sensor and actuator development, and microelectromechanical systems (MEMS) design. He has also worked to educate engineering students and professionals, and has taken part in efforts to increase participation of underrepresented engineering students in classrooms and laboratories. He has co-organized short courses for industrial engineers in Nonlinear Vibration and Time-Frequency Analysis, written a multi-media lecture series for Purdue engineering course ME 375 System Modeling, Analysis, & Control, designed and taught a graduate course in experimental nonlinear vibration analysis at the University of Cincinnati (UC), and worked as an instructor in a Modal Measurements Seminar at UC to expose practicing engineers to experimental and analytical structural dynamics and signal processing.
Email: deadams@purdue.edu

Robin Ward *Assistant Professor, University of Arizona College of Education, Teaching and Teacher Education*

[add introductory note emphasizing current relevant activities]
Dr. Ward received a B.A. in math/physics from Immaculata College and a M.A. in mathematics in 1989 from Villanova University. She worked as an aerospace engineer for General Electric and as a systems programmer for SEI, in Wayne, PA. She received her Ph.D. in mathematics education from the University of Virginia in Charlottesville and was an Assistant Professor in the Mathematics Department at California Polytechnic State University, San Luis Obispo from 1993-1997.

email: raward@email.arizona.edu

James Harris - *Chief Engineer, Dryden Western Aeronautical Test Range*
Mr. Harris is a member of the Systems Engineering Staff for the Facilities Directorate at Dryden Flight Research Center (DFRC). He is the Chief Engineer of the Western Aeronautical Test Range (WATR) and is responsible for the technical vision for all of the WATR facilities and systems. He is currently involved in the definition and development of the next generation of data acquisition, processing and display systems to be used to support future research flight test missions at DFRC.

Mr. Harris has been in the Aerospace Industry for thirty years. He has worked in the areas of aerodynamics, stability and control, flying qualities, flight controls, guidance and control, simulation, real-time data acquisition, processing and display systems, and systems engineering.

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Jeanne Holm, Knowledge Management Team, NASA Jet Propulsion Laboratory
(participation is pending)
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Ames Research Center
(participation is pending)

Michelle Davis - *Aerospace Education Specialist, NASA Dryden Flight Research Center*
Michelle Davis is involved with the development and implementation of the NASA Education Program, which is elementary through the university levels. The Dryden Education Program consists of teachers and student programs, services and products.

Michelle is a graduate of West Virginia University, Morgantown, WV. Originally from Pittsburgh, PA, she moved to Lancaster, California in 1996 where she began her NASA career as a member of the Aerospace Education Services Program (AESP), until 1998. As part of the AESP, she conducted teacher workshops and student assemblies.

Since 1998 Michelle's current job consists of the developing DFRC mission based products, student and teacher enhancing programs, state based systemic reform and education technology research. Before moving to California, Michelle taught middle science and high school physics in Prince George's County, Maryland, a suburb of Washington, D.C. She enjoys working in the local education community and is a private pilot.

Robert Lazarus - *Education Program Specialist, NASA Dryden Flight Research Center*
For the past six years, Robert Lazarus has been a fourth grade elementary teacher in Phoenix, Arizona. Prior to becoming Dryden’s Aerospace Education Specialist, he participated in his school district’s science task force, which was in charge of the piloting and the adopting of science curriculum. His involvement in the 2001 NASA Dryden Educational Workshop allowed him to integrate NASA lessons and activities regarding the five enterprises into his classroom, school, and district. These lessons and activities were correlated to Arizona state and local district standards.

Mr. Lazarus received his teaching certification from Arizona State University West and his Masters in Elementary Education from Northern Arizona State University in May 1999.

Letters of Support

Letters of support and commitment from Dr. Doug Adams at Purdue, and Matthew Miller, at Creare, have been received.

EVALUATION

Our proposal represents a hypothesis for creating value for science and technology education, which must be tested or otherwise quantified through metrics that adequately observe our strategy and its effect. We propose a three-step approach for testing our hypothesis:

- *Identify realistic, measurable* <u>*outcomes*</u> *that you expect to result from carrying out the project.*
- *Present a clearly defined plan to evaluate the degree to which project achieves project* <u>*outcomes*</u>*.*
- *Validate and verify performance goals, and outcomes used as the basis of our overall research design and methodology.*

Outcomes

The overall goal of the project is to enliven the learning of math and science through the study of real data from airborne activities - flight tests and science experiments. The data (archived or real-time), including aircraft performance parameters and experimental measurements from instruments on the aircraft, will be presented and interpreted in an appropriate way for students to understand.

The final outcome of the effort is for students to learn and appreciate real-world science and engineering activities. The intermediate outcomes will be learning methods and materials fostered by the proposed technological developments. These could include curriculum materials, data interfaces, and demonstrations of data delivery to the classroom.

In Phase 1, the metrics for measuring the intermediate outcomes will be developed. An evaluation plan for assessing student learning achievements will also be developed. The deliverables that will be generated in Phase 2 will be defined.

Approach

In this project, we propose to utilize "Use Case Scenarios" in which we brainstorm about how best to integrate real-world data analysis and interpretation into classroom instruction. Pre- and post-activity work with the classroom teacher would be useful in each case. Then, for each scenario, we will create a detailed evaluation plan, using the methods discussed below. Some examples of Use Case Scenarios follow:

1) In an undergraduate aeronautical engineering class, set up a flight simulator with actual data sets of aircraft flight parameters. Bring in the pilot to explain to the students what the data are that they observe. Instruct the students in how to interpret the data and variations or trends in the data. Allow them to study the data and draw conclusions about the activity. This exercise could be integrated into an existing curriculum.

2) During National Engineers' Week, bring a flight or science data set (strip chart records or electronic equivalent), along with flight video, to a high school math class. Have the engineer who took the data

explain the flight, the purpose of the experiment and the data. Have the students work with the data sets in a math exercise, such as statistical data analysis, graphing, or algebra.

3) Extend the educational work NASA is co-sponsoring with the Naval Postgraduate School to real-time Internet access in the classroom. In the NPS project, elementary school children are visiting the laboratory of the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) to observe real-time atmospheric physics data downlinked from science aircraft over a satellite communications link to the laboratory. The extension project would bring those same data to any classroom over the Internet. Either project personnel would need to be present in the classroom to explain the data, or accompanying materials would be studied in advance.

Evaluation Plan

Evaluation of the proposed technology and its use by students will take place periodically during development. This is Formative Evaluation. Evaluation of success or impact, called Summative Evaluation, occurs after the activity, assuming the technology works as planned. Whether summative or formative, the evaluations will have the following six phases:

- Develop a conceptual model of the program and identify key evaluation points
- Develop evaluation questions and define measurable outcomes
- Develop an evaluation design
- Collect data
- Analyze data
- Provide information to interested audiences

For each of the example cases above, the evaluations might be somewhat different. Some common elements would include:

- **Observations,** especially during the activity, to assess if the project is being delivered and operated as planned. Observations during the summative phase of evaluation can be used to determine whether or not the project was successful.
- **Surveys** of students and teacher to request their opinions about the activity, and about their more general views of math and science as career paths.
- **Interviews** with teacher and students about the activity, and also to specifically assess what they learned. Longer-term follow-up (after 1 year, after 2 years) to assess impact of the activity on knowledge, and on interest in math and science.
- **Testing** would be appropriate at the high school or college level. Incorporate problems in class work or exams that rely specifically on material covered in the activity. Use as a quantitative metric of learning from the proposed technology.

Relevant Experience

The proposed technology development and educational activities push the notion of virtual environments, remote observation and interactive events beyond what the participants are already achieving.

CIRPAS has developed a sophisticated data management system that brings real-time airborne science data into a laboratory for scientists to monitor and, in some cases, react to with guidance to the flight parameters. Dr. Schoenung is working with CIRPAS to bring elementary school students to the laboratory in Marina, California to observe this activity. (The activity proposed here could bring the real-time data to the classroom, rather than transporting the students.) Dr. Schoenung is also responsible for evaluation of the impact of the activity through interaction with the students and teacher. This effort is co-sponsored by NASA, and Dr. Schoenung will coordinate with NASA personnel in delivering the evaluation in the fall of 2002.

Dr. Schoenung is also involved in oversight of the Outreach and Education elements of Code Y's Uninhabited Aerial Vehicle Science Demonstration Program (UAVSDP). In this program, two science campaigns will be carried out in late summer 2002. Each will provide both aeronautical and science data sets, some in real-time and some delivered with the return of the aircraft. These campaigns include elements of education and public outreach via web site updates, news videos, and significant curriculum material. In both projects, students are involved in ongoing data interpretation and scientific research.

APPENDIX

Related RBNB efforts

The timing for applying new technologies to education applications should be carefully considered; sometimes a technology is applied too early possibly resulting in a one-time demonstration that, because of its immaturity, cannot easily survive beyond the end of Phase II prototype development. The Ring Buffered Network Bus was conceived and prototyped with NASA investment, and since then has been commercialized and used within and outside the Agency. Continuous improvement and a growing variety of applications leverage off each other and mitigate the risks associated with long term success of this project. A few examples of relevant RBNB applications are provided here to illustrate the breadth and depth of RBNB capabilities.

Distributed Real Time Decision Making (NASA Dryden)

Full-scale flight testing is exceedingly expensive and places a premium on achieving critical test points while minimizing down time for data analysis and re-fly requirements. For the past several years NASA Dryden has been using RBNB Data Turbines to realize significant increase in flight test efficiency. A few example are shown below.

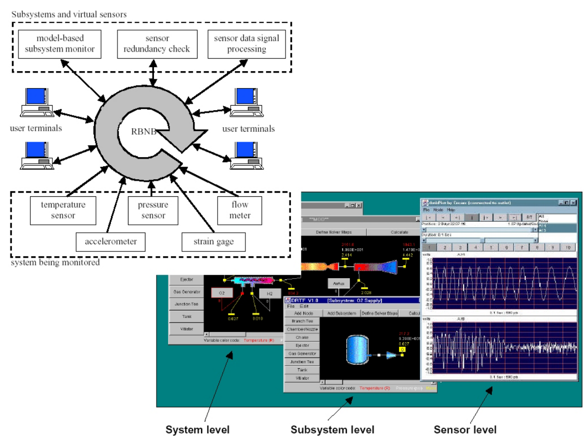
Dryden Flight Research Center EC97-44077-3 Photographed May1997
This modified Lockheed L-1011 TriStar operated by Orbital Sciences Corp. lifts off on its first flight in NASA's Adaptive Performance Optimization study. (NASA/Tony Landis)

RBNB technology combines on-board data acquisition and analysis with remote display and messaging to support real-time collaborative decision making by the flight crew, mission control, and on-site and remote client engineers. Using these tools it is now possible to immediately confirm data usability, identify anomalies, and develop mid-mission flight profile realignments. For the L-1011 Adaptive Performance Optimization program, RBNB enabled realtime evaluation of slow cruise maneuvers, demonstrating effectiveness of the experiment as it happened and saving thousands of dollars in continued flight test costs.

The X-38 research vehicle is a research prototype of an unpowered vehicle that returns from the space station by gliding to pinpoint landings via a large parafoil. Knowledge of the mass and inertia characteristics are critical elelemnts of the flight control system for this vehicle. RBNB is used during inertia measurement ground tests to provide quick-look and post test data access and subsequent analysis visualization using established commercial analysis packages like Matlab™.

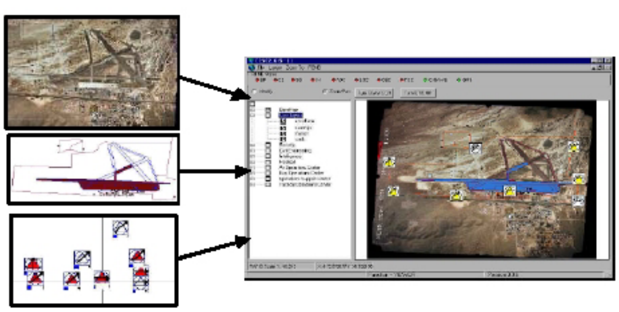
Dryden Flight Research Center EC98-44727-2 Photographed 1998
X-38 NASA/Dryden

The X43 “Hyper-X” is a small advanced hypersonic research vehicle launched from the nose of a rocket. The distributed test team needed to interpret data quickly after the rocket accelerates out of visual range. RBNB is used to manage the cost-effective delivery of over 1000 measured parameters between NASA Dryden (California) and NASA Langley (Virginia) with two key benefits. First, an entire control room of remote engineers enables participation in the live flight test operation without the travel expense. Second, the remote control room performs value-added calculations to drive 3-D graphics so that both Dryden and Langley can easily visualize overall vehicle dynamics.



The development of object-oriented software tools to aid the design, analysis, implementation and use of machinery health management systems is needed. NASA is developing an open, scaleable health management software system that will enable the configuration and initiation of remote algorithms that will reduce raw sensor data into relevant health information for both novice and sophisticated designers and users. The system is intended to be useful for a variety of airborne and terrestrial prognostic and diagnostic automation applications. A standard way of connecting dissimilar components from different vendors on different platforms is needed, and this project uses the Ring Buffered Network Bus, as RBNB is well suited to the task of being the mechanism for interconnecting components.

Data Fusion and Display (USAF Force Protection Battlelab)



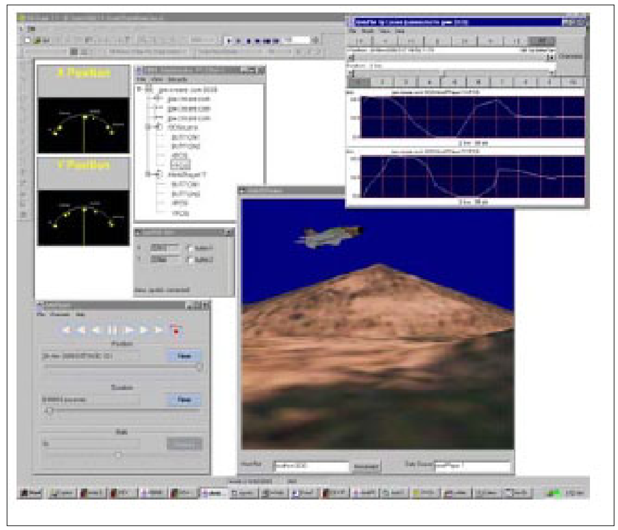
Success in combat means all parties must share a common operational picture that reflects a fusion of disparate geographic, sensor and unit status information.

As part of the JEFX 2000 exercise RBNB technology was deployed as the “glue” to build a distributed common operational picture tailored to the combat support forces needs. Defensive position locations, sensor reports, and real-time messages were consolidated, displayed, and distributed using standard TCP/IP protocols.

Synchronized Display, Analysis, and Playback (USAF Air Armament Center)

Modern aircraft munitions and system testing at Eglin AFB involves multiple tracking technologies, high data rate multiple channel telemetry, sophisticated video trackers and recording systems, and critical mission control and safety requirements. Traditionally these needs have been met by custom designed, often proprietary, complex, and expensive standalone systems.

Currently RBNB technology is being used to design the Next-generation Eglin Data-management System (NEDS). The NEDS system will run on inexpensive networked PCs. Each mission display, whether local in Mission Control or off-site, will have the ability to individually select data sources or parameters of particular interest, time synchronize the data from multiple independent sources, and seamlessly switch between real-time streaming data and previously recorded mission information.



Other ongoing activities not discussed here include Sensor Webs / Electronic Noses and Homeland Security